AERIAL REFUELING MODERNIZATION

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EXECUTIVE SUMMARY

An aerial refueling modernization program has been proposed by the US Air Force which includes reengining of KC-135s and procurement of KC-10s. The modernization program will help satisfy growing refueling requirements, reduce KC-135 operational and environmental problems, and provide a flexible tanker force to satisfy a wide range of strategic and tactical missions.

Analyses show that additional aerial refueling capability is currently needed for optimum low-level penetration routes to support Strategic Air Command (SAC) B-52s in the Single Integrated Operational Plan (SIOP), and the requirements for tanker support will increase when the B-52s begin to carry Air Launched Cruise Missiles (ALCM). Compounding this strategic planning problem is the requirement of refueling contingency operations. Forecast aerial refueling requirements for combined SIOP and contingency missions are compounded to the extent that one or both missions could be seriously degraded without tanker modernization.

Increased tanker requirements aside, there are specific KC-135 operational and environmental problems. These include limited thrust and fuel offload capabilities, excessive fuel usage, chronic water augmentation (takeoff thrust) problems, and excessive engine noise and gaseous emmisions which currently impact metropolitan areas throughout the US. Reengining the KC-135A with the CFM56 engine will significantly reduce these problems.

The reengined KC-135 (KC-135R) provides substantial improvement over KC-135A performance. Fuel offload capabilities at all refueling ranges are increased and engine thrust is improved, significantly reducing basing constraints. Additionally, the KC-135R is 25 percent more fuel efficient, six times quieter and substantially less polluting than the current KC-135A.

The Air Force would save 180,000 gallons of fuel per year per aircraft through reengining, complying with the National Energy Conservation Policy Act (P.L. 95-619) which requires that the DOD reduce its energy use. Reengining all 615 KC-135As would provide an offload capability of 923 KC-135A equivalents while saving 110 million gallons of fuel per year.

Reengining all KC-135As, however, is not sufficient to support the growing aerial refueling demands. The wide bodied KC-10 offers distinct capabilities, including a three-to-one fuel offload advantage over the KC-135A, a large cargo carrying capacity, increased flexibility, and long range mission support without reliance on enroute basing and overflight rights.

A mix of KC-135Rs and KC-10s provides the necessary modernization to meet future aerial refueling needs. Furthermore, simultaneous production of KC-135Rs and KC-10s is the only way to produce sufficient tankers in time to satisfy late 1980s requirements.

I. INTRODUCTION

In times of crisis, the requirements for the KC-135A are dramatic. The existing tanker force was originally acquired primarily to support strategic bombers. Today, in addition to supporting the Single Integrated Operational Plan (SIOP), it must also support:

- Airborne command posts (EC-135 and E-4)
- Strategic reconnaissance
- Airborne warning and control systems (AWACS and ABCCC)
- General purpose tactical aircraft
- Strategic airlift
- Conventional bomber operations

To assist in understanding the requirement for a modernized aerial refueling force, this paper: (1) discusses the benefits of aerial refueling, (2) addresses tanker support for the operational commands, (3) discusses KC-135A enhancement alternatives for meeting these requirements, (4) updates economic analyses, and (5) presents observations regarding tanker force modernization.

II. THE AERIAL REFUELING MISSION

The KC-135A was designed and built in the late 1950s and early 1960s to refuel strategic bombers. Since that time, the Military Airlift Command (MAC), the Tactical Air Forces (TAF), and the Navy have all increased the numbers and types of aircraft that require tanker support. In addition, the threat, location, and operational concepts for each mission have changed. As a result, the need for aerial refueling support greatly exceeds current capabilities.

Current plans call for US bombers to penetrate Soviet air defense systems at low altitude to reduce their vulnerability. However, low-altitude flight consumes about twice as much fuel per mile as high-altitude flight. As a result, aerial refueling enhances target coverage and aircraft recovery.

In response to increased threats in NATO and elsewhere, aerial refueling is planned to increase the effectiveness of our general purpose forces. The rapid reinforcement of the TAF is essential to ensure that an adequate force balance ratio is attained early in the conflict. Without aerial refueling, tactical aircraft deploying to Europe would be forced to stage through enroute bases, and response time would be extended from hours to days, particularly during inclement weather. Rapid deployment of tactical air forces to the Far East is impossible without aerial refueling.

The number of major overseas Air Force installations has decreased from about 70 in 1968 to less than 30 today, and operations from the remaining bases are subject to more stringent host-nation conditions concerning the nature of permissible operations. As the concept of augmenting in-place overseas military forces during a crisis with CONUS-based forces evolved, the use of these foreign bases for refueling became critical to military deployments.

However, the growing political and economic influence of Third World countries has made availability of enroute staging and refueling locations questionable, as was the case during the 1973 Mid East war, the recent deployment of fighters to Egypt, and the delivery of F-16 aircraft to Israel. Aerial refueling of fighter, airlift, reconnaissance and bomber aircraft is the only alternative to this development. Furthermore, the geo-political climate has made the capability of the United States to project forces (e.g., rapid deployment force) worldwide even more important (e.g., Persian Gulf). The 1973 Mid East war highlighted this requirement and our need to support allied nations quickly.

The Strategic Air Command (SAC), with Air Force Reserve and Air National Guard augmentation, must meet increased air refueling demands. However, there has not been a corresponding increase in refueling resources.

III. TANKER FORCE REQUIREMENTS

Currently, all 615 PAA KC-135As would support the execution of the SIOP. However, non-SIOP tanker requirements continue to grow in importance because of the previously discussed NATO and contingency (including RDF) needs--as well as the political restrictions on basing and overflight rights. These requirements are in addition to the tanker needs of a fully-generated SAC bomber force. Currently, the Joint Chiefs of Staff would have to divert some tanker assets for the refueling of general purpose forces and accept the resulting degradation of the SIOP.

A. Single Integrated Operational Plan (SIOP)

SAC analyses show that additional KC-135As are already needed for all strategic bombers to follow optimum tactics in the SIOP, thereby increasing the probability of mission accomplishment and enhancing bomber recovery.

As ALCMs enter the inventory, the B-52G force will be loaded externally with ALCMs. With this configuration, the B-52G force will launch their ALCMs and then penetrate enemy defenses with any remaining weapons. With external ALCMs, the B-52G will suffer range degradation due to increased drag and fuel reduction resulting from the increased weight of the missiles.

As additional ALCMs enter the inventory, B-52s will be configured to carry cruise missiles both internally and externally. The B-52 force may then be used in a standoff role (with a modest reduction in tanker requirements), but some remaining bombers may continue to penetrate.

Should additional B-52s also be converted to the ALCM carrier role, the aerial refueling requirement for a total B-52 force may be further reduced. Nevertheless, future refueling requirements will still exceed today's capability due to increased drag from ALCM carriage, ALCM weight, planned tactics, and the need to reach recovery bases.

Withdrawing refueling resources from the SIOP to support contingencies could have serious consequences. Depending on tanker availability, tactics might be degraded to the point that bomber effectiveness would be seriously jeopardized and planned targets might not be hit. Furthermore, the impact of withdrawing tankers from SIOP in favor of contingency operations cannot be measured solely in terms of target coverage, but must also (even if qualitatively) be assessed in terms of force recovery.

B. Non-SIOP Requirements

Department of Defense planning documents have noted the growth of aerial refueling requirements to support contingencies in NATO, the Mid East, the Persian Gulf, and elsewhere. The required tanker support varies with the contingency scenario, but the Air Force must have a refueling force that is capable of responding across a wide spectrum of conditions.

The need to rapidly deploy forces to trouble spots and to supply them as necessary is critical to deterring hostile actions and to enhancing US war fighting capabilities in the event of actual hostilities. This need has been recognized, and actions are underway to make all airlift forces air refuelable by 1984. The complementary modernization of the tanker force is necessary to fully realize US rapid deployment capabilities.

A variety of options are currently planned to provide refueling support for the deployment and employment of Air Force aircraft in the event of a conflict between NATO and the Warsaw Pact. In addition, recent events have focused attention on potential contingencies other than NATO (such as the Mid East and the Persian Gulf) and studies have examined tanker requirements for such contingencies.

Currently planned options to support contingencies would require a substantial portion of the KC-135A force, and studies have demonstrated the utility of even more tanker support. Without increased tanker resources, US response flexibility would be constrained due to SIOP degradation.

C. Combined Requirements

If a developing European or other contingency should result in advanced force readiness posture requiring generation of the bomber force, then both contingency and SIOP tanker requirements would have to be met simultaneously. Detailed examination of refueling support requirements indicates that a portion of the KC-135s committed to a contingency actually underway could also be available to support the SAC bomber force. Some of the tankers are

typically performing the contingency task (airborne and already refueling) or landing and being readied for subsequent missions. Depending on basing location and sortie rates, the majority of tankers may not be available for SIOP bomber refueling.

Therefore, while the combined requirements are not additive, they are not independent. In addition, analysis of the combined requirement shows that reengining all KC-135As will not completely satisfy the tanker requirement. As a result, continued production of the KC-10 with its unique tanker and cargo capabilities, will be a necessary complement to the reengining program. The resulting mixed force will satisfy combined SIOP and contingency requirements while providing the flexibility to effectively manage requirements ranging from "fuel intensive" to "boom intensive" missions.

IV. BENEFITS OF THE MODERNIZATION PROGRAM

Independent of the actual tanker requirement, there are specific KC-135A operational and environmental problems that have implications for tanker force modernization.

A. KC-135A Deficiencies

Past and current structural and avionics modifications will extend the KC-135A's service life beyond the year 2000. However, performance shortcomings are caused by the J57 engine and the aerial refueling system, both 1950 technology systems. These deficiencies are summarized below.

1. Limited Thrust and Fuel Offload Capability

The KC-135A has the lowest thrust-to-weight ratio of any aircraft in its class. Efficient and effective KC-135A operations are degraded primarily by insufficient total thrust during the takeoff phase and by the high fuel consumption characteristics of the J57 engine.

To ensure a safe takeoff and climbout after experiencing an engine failure on non-SIOP missions, a KC-135A at maximum gross weight requires 12,700 feet of runway (sea level-standard day). Only six airfields in the CONUS have runways long enough to accommodate the KC-135A at maximum gross weight using peacetime safety criteria.

To take off from a base with a 10,000 foot runway (there are about 75 in CONUS), a KC-135A must actually take off with approximately 30,000 pounds of fuel less than its maximum capacity. This results in the generation of additional KC-135A sorties and reduced refueling offloads, severely limiting tanker ability to support extended range missions.

Excessive takeoff distances also limit the bases available for dispersal and thereby lower the probability of launch survival. Reengining would double available dispersal bases while allowing takeoff at maximum gross weight.

Water augmentation, requires with the J57 engine to increase thrust during takeoff, is a chronic problem that causes both operational and maintenance penalties. Water system reliability is a problem. In addition, the demineralized water used in the engine may not be available at overseas locations, forcing aircraft to operate with reduced payloads or risk engine damage from impure water.

2. Operations and Support

Rapidly escalating fuel prices coupled with diminishing world-wide petroleum reserves demand efficient fuel usage by the Air Force in support of the National Energy Conservation Policy Act. Reengining a KC-135 with the CFM56, which is 25 percent more fuel efficient than the J57 will save about 180,000 gallons of fuel per year per aircraft, or over $200,000 per aircraft in FY 81 dollars. For a totally reengined force this amounts to 550 million gallons of fuel saved at a cost of $614 million over a five year period (assuming the rate of growth in fuel prices equals the general inflation rate).

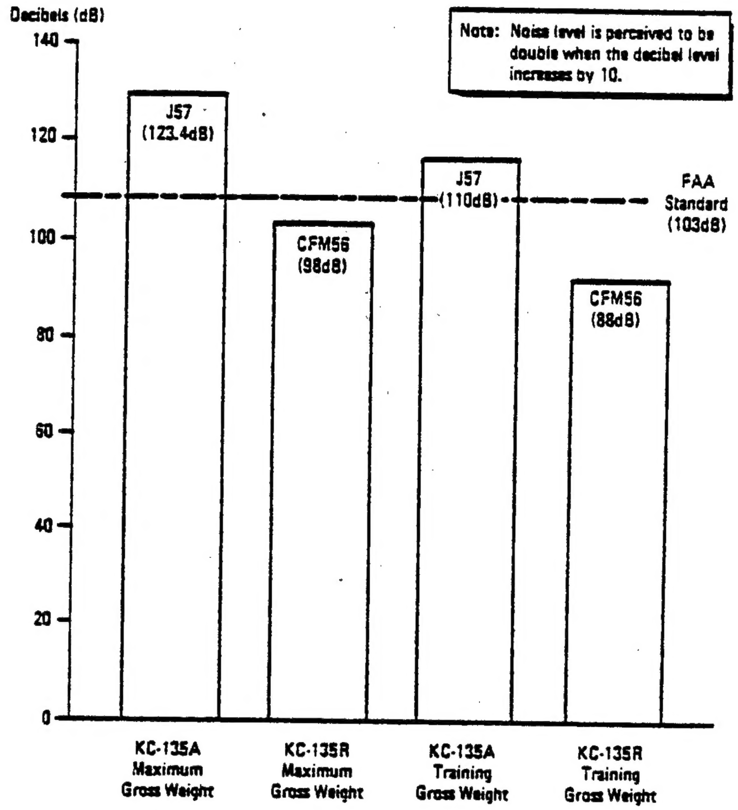
Additionally, maintaining the aging J57 engine is becoming increasingly more difficult and expensive. It is based on 1950 technology and has already been reworked beyond reasonable expectations. Parts are no longer mass produced, but have to be specifically ordered or cannibalized. An estimated $1,520,000 in engine rehabilitation costs per KC-135A are programmed to restore the J57 engine to its original performance specifications.

3. Environmental

The environmental problems of the KC-135A can be categorized into three areas: noise, smoke, and gaseous emissions.

The KC-135A, operating at maximum takeoff gross weight, is the noisiest aircraft in its class (exceeding the Concorde). Its noise level is four times greater than the FAA standard. Even at training gross weights, the KC-135A is well above the FAA FAR-36 Effective Perceived Noise Level limit of 103 dB. Figure IV-1 shows that reengining will allow the KC-135 to comply with this regulation. In each of the takeoff examples shown, the KC-135A will be perceived to be six times louder than the KC-135R.

FIGURE IV-1
COMPARISON OF ENGINE NOISE DURING TAKEOFF
(3.5 NM From Brake Release)



Although military aircraft are presently exempt from the regulation (which will be mandatory for all civil aircraft by 1985), noise has been a dominant source of tension with the public, particularly at locations where Air National Guard and Air Force Reserve units operate at civil airports (9 locations). Overseas basing of KC-135As is also threatened by citizen reaction to the noise problem (e.g., residents of Fairford, England).

Smoke and gaseous emissions are of growing concern to the Air Force. No current engine can meet all future aircraft engine emission standards, but the J57 emissions far exceed those for the CFM56. Table IV-1 compares emissions and smoke for the J57 and CFM56. Pressure is mounting in the civil sector, and the State of California is currently suing the Department of the Navy over smoke from aircraft engines operated in test cells. (J57s are among the engines.)

TABLE IV-1

ENGINE EMISSIONS

Engine	Carbon Monoxide*	Hydro Carbon*	Nitrous Oxides*	SAE Smoke Number
J57 Wet	85.0	103.80	12.2	65
J57 Dry	38.7	31.50	5.8	57
CFM56	5.3	0.09	4.7	22

B. Assessment of Modernization

There are two basic components to the tanker modernization program--modification of the current KC-135A and the acquisition of additional KC-10s. Replacement of the J57 engines with new technology engines will eliminate many of the current operational, environmental, safety, and maintenance problems of the KC-135A. Three engines (CFM56, TF-33-P-7, JT8D-209B) were evaluated for the reengining program and the CFM56 was selected in December 1979.

Even reengined, the KC-135 force will not satisfy total tanker requirements and will provide only a limited capability at long ranges. During deployment of combat resources to the Mid East/Persian Gulf, or Africa region, the KC-10 is needed.

The KC-10 has the unique capability of providing both long range aerial refueling and airlift support. It will permit deployment and reinforcement of US military forces without reliance on uncertain intermediate foreign basing rights, and its large cargo and fuel offload potential will provide the capability to deploy tactical fighter forces including support equipment and personnel simultaneously. Additionally, the KC-10 has the capability to expand strategic airlift capability, particularly with respect to long range movement of oversized cargo, when not otherwise involved in air refueling operations.

Reengining of the KC-135 and procurement of the KC-10 appears to be the most promising way to modernize our tanker force. Additionally, producing both aircraft will provide a cost-effective tanker force while providing flexibility for both SIOP and TAF missions.

1. Capability Improvements

Fuel-offload curves for the KC-135A, the KC-135R, and the KC-10 are shown (pg 9) in Figures IV-2 and IV-3. Figure IV-2, which is representative of a forward recovery mission, assumes that tankers land at a base 1,000 NM away after off-loading their fuel. To illustrate how the chart is read, if the refueling point is 6,000 NM from takeoff, the KC-135A would have no offload capability, the KC-135R could offload about 40,000 pounds of fuel and the KC-10 could offload about 85,000 pounds.

Figure IV-3 assumes tankers fly a radius (or round trip) mission. This type of mission is more likely for a scenario in which tankers are continually being used and recycled. Thrust limitations and runway length typically restrict the KC-135A to 270,000 pounds gross takeoff weight for these missions.

The effectiveness of the KC-135R and the KC-10 compared to the KC-135A can be simplistically measured by comparing the aircraft fuel offload ratios at various distances. The KC-10 and the KC-135R have increased offload capability over the KC-135A at all ranges. Figure IV-4 (developed from Figure IV-2) shows an effectiveness comparison for tankers with a 1,000 NM recovery leg while Figure IV-5 (developed from IV-3) shows an effectiveness comparison for tankers on a radius mission. For example, from Figure IV-4, if the distance to the refueling point is 4,000 NM, the KC-135R could offload 1.6 times as much fuel as the KC-135A, and the KC-10 could offload 3.2 times as much.

As discussed earlier, due to safety constraints, the KC-135A is unable to take off with a full fuel load on non-SIOP missions, while the KC-135R and KC-10 would take off at their maximum gross weight.

This analysis shows that the reengined KC-135 will generally be about 1.5 times as effective as the KC-135A on SIOP missions and on contingency missions the KC-135R will be over 1.5 times more effective than the KC-135A for distances greater than 1750 NM (see Figure IV-5). The KC-10, to be used primarily on contingency deployment missions, will be about 3.0 times as effective as the KC-135A at the same range.

These ratios however, do not completely measure overall operational capability. Fuel transfer problems often involve boom as well as fuel offload capability.

Strategic missions, where large capacity aircraft require refueling, are generally classified as fuel intensive while deployment and employment of contingency forces with numerous fighter aircraft are generally boom intensive missions. Tanker modernization with KC-135Rs and KC-10s will provide a flexible tanker force to effectively and efficiently support a broad range of missions.

FIGURE IV-2
TANKER COMPARISON (1,000 NM Return Mission)

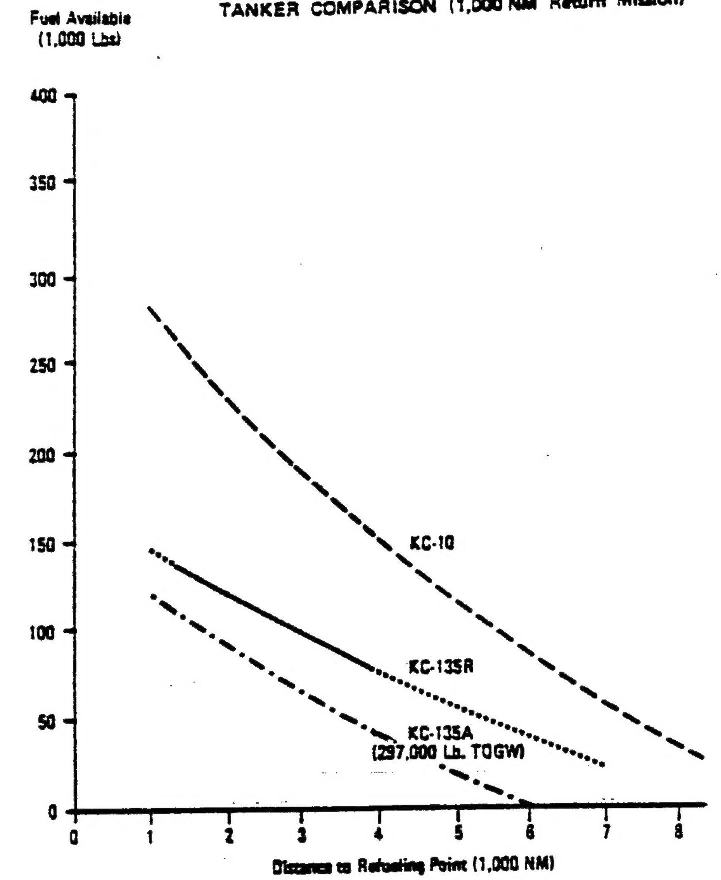


FIGURE IV-3
TANKER COMPARISON (Radius Mission)

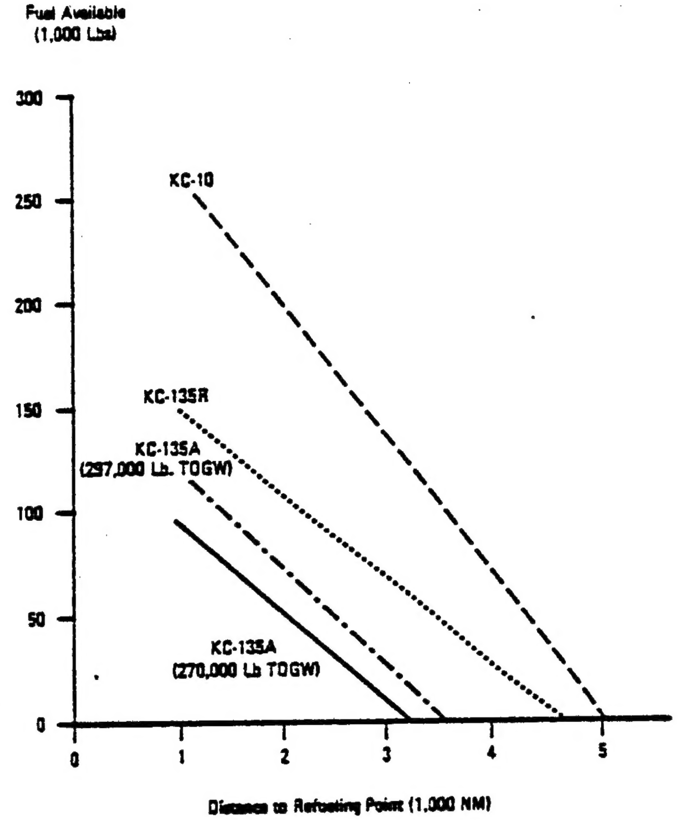


FIGURE IV-4
TANKER EFFECTIVENESS COMPARISON (1,000 NM Return)

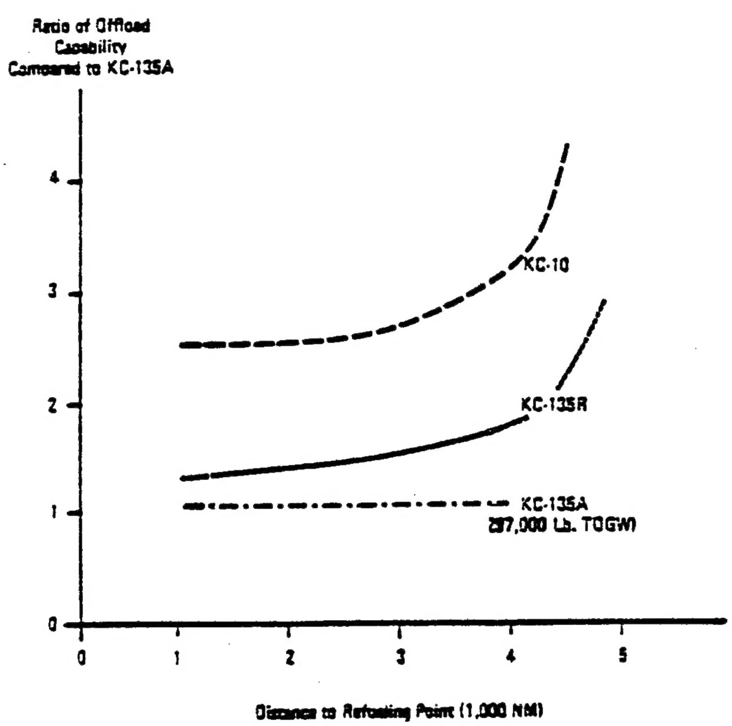
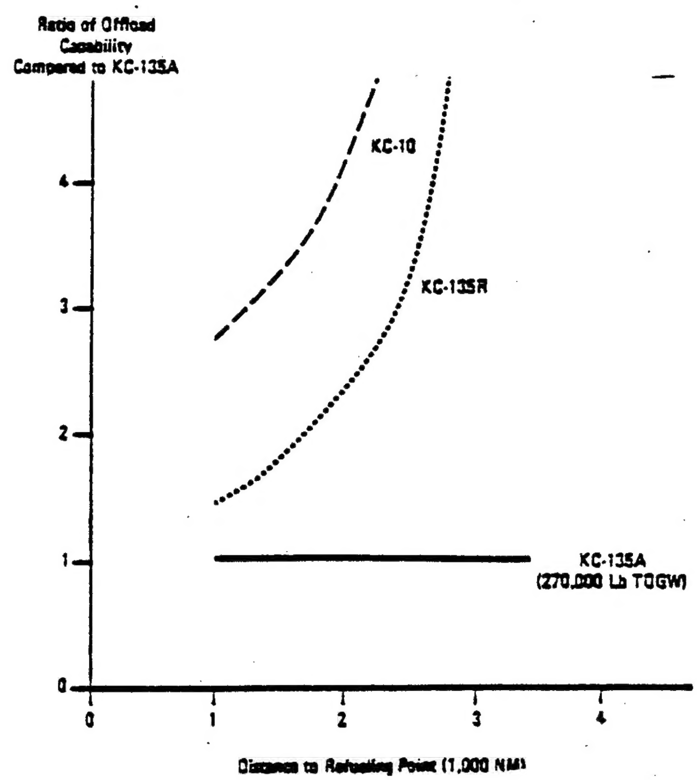


FIGURE IV-5
TANKER EFFECTIVENESS COMPARISON (Radius Mission)



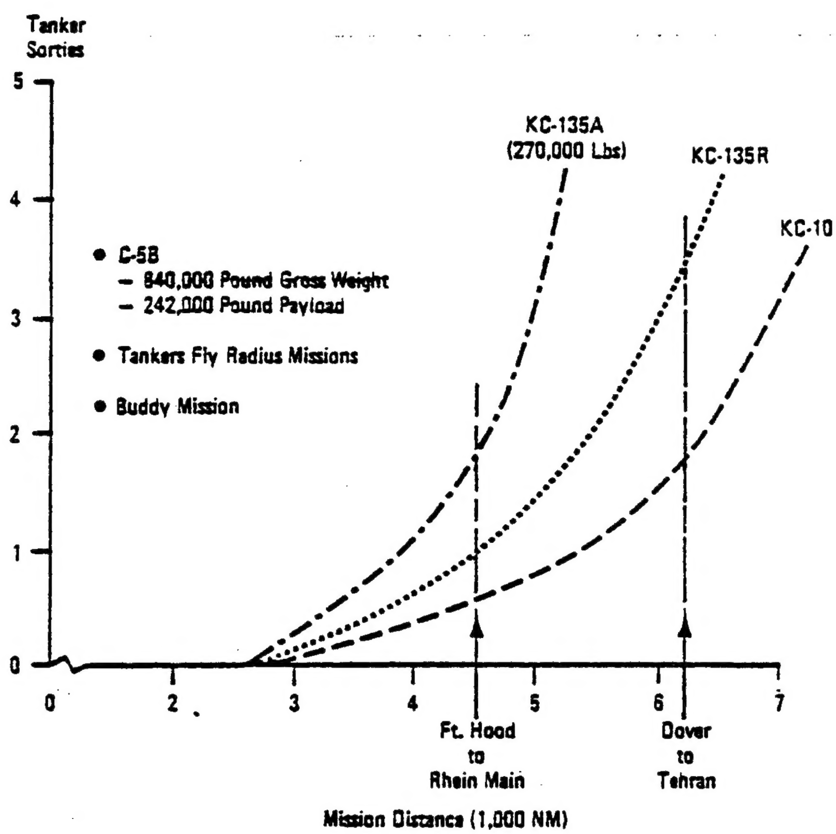
The relative capabilities of these tankers in a generalized contingency mission without overseas basing can be seen in Figure IV-6, which shows the number of tanker sorties required for the refueling of a C-5B carrying maximum payload (e.g., two M-60 tanks) as a function of mission range. We assume the KC-135A takes off at about 270,000 pounds, while the other tankers take off at a maximum gross weight.

For the C-5B to fly 4,500 NM with maximum payload, two KC-135As, one KC-135R, or one-half KC-10 are required. The KC-135A is not able, without enroute basing, to support the C-5B with this payload for a 5,500 NM mission. The KC-10 is the only tanker capable of supporting a C-5B on a 6,500 NM buddy mission (i.e., where the tanker flies along with the C-5B instead of meeting it enroute).

In addition, the KC-10 could fly more hours per day than either of the KC-135s, thus increasing its average daily sortie rate and the number of airlift refuelings supported.

In summary, the KC-135R and KC-10 provide substantial improvements over the KC-135A. Although these improvements are important in the SIOP missions, they are more pronounced in the aerial refueling of general purpose aircraft because of the performance restrictions of the KC-135A in general purpose missions.

FIGURE IV-6
TANKER SUPPORT REQUIRED FOR C-5B



2. KC-135 Reengining Cost Considerations

There are no current plans to retire any of the KC-135 force because the basic KC-135A airframe will last well into the next century at projected flying hour rates. An analysis was, therefore, undertaken to assess economic considerations relative to the reengining program. Table IV-2 compares the 20-year life cycle costs for the KC-135A and the KC-135R with two cost growth assumptions for fuel (0% above inflation and 10% above inflation).

TABLE IV-2

20-YEAR TANKER COSTS PER PAA
(Millions of FY 81 Dollars)

Cost Category	0% Annual Fuel Cost Growth KC-135A	0% Annual Fuel Cost Growth KC-135R	10% Annual Fuel Cost Growth KC-135A	10% Annual Fuel Cost Growth KC-135R
Acquisition	$ 0.0	$14.2	$ 0.0	$14.2
J57 Rehab	1.5	0.0	1.5	0.0
Class IV Mods	0.8	0.8	0.8	0.8
20-Year O&S (Except Fuel)	18.8	17.4	18.8	17.4
20-Year Fuel ($1.11/Gal Base)	15.8	11.9	45.3	34.0
20-Year Life Cycle Costs	36.9	44.3	66.4	66.4
20-Year Life Cycle Costs Per KC-135A Equivalent	36.9	29.5	66.4	44.3

1. 1.27 Crew Ratio; 326 flying hours per year.
2. Reengining costs based on a buy of 300 KC-135Rs (6 per month) and includes a quick start capability.

The key measure of effectiveness for the reengining program is the 20-year life cycle costs per KC-135A equivalent. Under the assumption that fuel costs will rise at the same rate as inflation, the KC-135R will cost more than the KC-135A because of the initial acquisition costs. However, since it will provide approximately 1.5 KC-135A equivalents, the KC-135R would reduce costs per equivalent by $7.4 million.

If annual fuel costs rise at 10 percent above inflation, fuel savings would almost pay for the initial acquisition costs. More importantly, the cost per KC-135A equivalent would be reduced by $22.1 million.

Thus, KC-135 reengining would provide all the benefits described earlier (reduced noise and emissions, fuel savings, improved maintainability, elimination of takeoff problems, and improved offload capability at all ranges) while improving the cost-effectiveness of the tanker force.

V. OBSERVATIONS

Present aerial refueling requirements for combined SIOP and contingency missions exceed current offload capability. Introduction of ALCM causes a range degrade of the B-52G carrier due to displaced fuel and increased drag and will increase offload requirements when the ALCM is fully employed. Future B-52 ALCM tactics may decrease the requirement slightly but the combined requirements will still greatly exceed current capability.

The aerial refueling modernization program includes two complementary actions, KC-135 reengining and KC-10 procurement. The resulting tanker force will have the flexibility to cost-effectively satisfy the offload and boom requirements for a wide range of SIOP and contingency missions.

The KC-135A will be flying well into the next century. However, it has operational and environmental problems that include: limited thrust and fuel offload capabilities, excessive fuel usage, water augmentation problems, excessive engine noise, and environmental emissions.

Reengining the KC-135A with the CFM56 engine will alleviate these problems and eliminate maintainability concerns associated with the 1950s technology J57 engine.

In compliance with the National Energy Conservation Policy Act (P.L. 95-619), 180,000 gallons of fuel per year per aircraft would be saved through reengining. If all 615 KC-135As were reengined, 110 million gallons per year would be saved at a five year savings of over $614 million (assuming a constant fuel cost of $1.11 per gallon).

Using offload capability as a measure to estimate the equivalent capability of each aircraft, on a typical SIOP mission, on the average, the KC-135R is 1.5 times as capable as the KC-135A and the KC-10 is 3.0 times as effective as the KC-135A.

Economic analysis shows that the KC-135R will be cost-effective in providing offload capability on both SIOP and contingency missions.

The KC-10 offers unique capability beyond that of the KC-135R on extended range and fuel intensive missions while adding cargo carrying capability, thus complementing the KC-135R over a wide range of required missions.

A mix of KC-135Rs and KC-10s provides the necessary modernization to meet future aerial refueling needs and, with simultaneous production, can provide tanker capability in time to satisfy late 1980s requirements.